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An Essay On the Nature of Science

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essay

AN ESSAY ON THE NATURE OF SCIENCE

R. W. Hamming May 13, 1997

Scientists and engineers have been repeatedly urged to become involved in the science-pseudoscience-antiscience discussions that are raging around, especially in the courts where, if you believe even part of the newspaper reports, nonsense seems at times to reign. Therefore, I recently gave some thought to the topic of exactly what science is. The results were not what was wanted by the urgers, or by me, but honest science requires reporting what you find and not suppressing it.

Science has two faces, the methods used, and the results obtained; in this essay we are interested only in the methods used in science. Science is not a unique thing to be discussed as if it were; it is at best a loose collection of remarks which have been made by assorted individuals, and at worst the remarks are totally misleading.

I believe it was in the 60's that a new edition of a famous dictionary came out and caused a furor. The editors said bluntly that they would not attempt to prescribe, rather they would describe how words were used. There is after all, no sacred standard to appeal to; the best writers over the centuries, the current best writers, or the (whose?) best critics, are all arbitrarily defined and give no absolute standard. This caused great anguish among those who want an authorative source, such as the New Yorker Magazine book reviewer, and the author of the Nero Wolfe detective stories who had the hero tear pages out of it and put them in the fireplace.

Similarly I expect that those who like to have authorative statements to appeal to will not like this essay which says that I will not attempt the foolish act of prescribing how science should be done, rather I will describe how some people do it currently or have done it in the past.

In the past we have personified science as if it were a single person - "Science says ...", "Science has shown ...". The most casual examination will show that "science" as actually done is at best a loosely organized mob of individuals, each one mainly pursuing their own interests. So far as I can see, there is no formal restriction, no baptismal ritual, for who can call themselves a scientist, nor who can claim to speak in the name of science. There is a bit of structure in science, for example the National Academy of Science actually has some authority to speak for scientists, and what they say has some prestige, but it was originally created for the benefit of Congress. Money granting organizations also have some influence, but again no absolute authority to pronounce on what science is. There is no infallible

Pope of science.

Usually there is a large gap between those who practice science from day to day and the philosophers who pontificate about what science is; the one does not worry about what science is but simply does their thing which they call "science", while all too often the other have never really done science at all and does not know what they are talking about. Now and then a competent scientist has written on what they thought science was, but these are rare indeed.

Socrates, Plato, and Aristotle all seemed to have believed you could talk about anything, truth, beauty, justice, and the gods. But even in their time there were the mystery cults who said you could not talk about the gods, you had to experience them. Thousands of years of legal codes, from Hammurabi on, have not produced justice, only legalities. And "What is truth?" is a very old question that has not been answered adequately. Finally, it is widely said that beauty is in the eye of the beholder, not in the object itself.

Even a more modest goal such as defining what mathematics is has not resulted in widely accepted definitions - rather upon mature thought one comes to realize that again, probably, "mathematics must be experienced", and all the talking about mathematics is inadequate to say what it is.

Thus it appears to be useless to try to define sharply what science is or is not; indeed science may be a matter of degree and not a yes/no situation. At best one can talk around it and repeat some of the formulations that have been attempted, along with their limitations.

1. A very common claim is that science depends on controlled experiments, but the first science to arise, astronomy, up until very recently, could do no controlled experiments, they could only choose when and at what they would look.

2. Another common claim is that a science must make verifiable predictions. But evolution is generally considered to be a scientific theory, yet in the past it has made almost no predictions, just assertions that this is how it probably happened in the past. Evolution in the past has been more explanitory than predictive.

3. Another common claim is that science uses mathematics, but for a long time botany and zoology, for example, used almost no mathematics beyond simple arithmetic and statistics. Many people in the "harder sciences" do not think that "management science" is a science no matter how much mathematics they may use. Economic science is another doubtful science, although often it uses elaborate mathematics; indeed it has been said by some people that those fields which use the word "science" are not sciences! Again, astrology uses a fair amount of mathematics to locate the

constellations, stars, and planets, but among scientists it is reviled as not being scientific.

4. A very strong component of doing science in the past has been the positive effort to show that you are wrong; we seem these days not to do it as much as I was taught to do, and as a result (due perhaps also to the "publish or perish" rules) much of what is published is later found to be "not quite right". It is always fair to ask, "What kinds of evidence will you accept that you are wrong?" Before publishing a scientist should have thought long and deeply about that question and have a ready answer that is serious, not flippant. In a sense, the more positive the person is that they are right, the less of a scientist they probably are.

5. Another claim is that science is based mainly on observations, but this is hardly true of some modern science like relativity and quantum mechanics where philosophical claims of "the relativity of events" is assumed, along with symmetry, and all observations are correspondingly interpreted. Cosmology is a good example of much theory based on little observation - after all there is only one universe to observe!

6. Popper has emphasized the necessity of disproof, but while it is a nice criterion it is surely not absolute. A theory, such as the Ptolmaic, which can fit any set of observations (by using enough epicycles), is not a scientific theory; a theory which can explain every set of data is therefore not a scientific theory, according to Popper. Unfortunately, we have often had theories which we regard as scientific and yet we know (but prefer usually to ignore) some counter evidence. A counter example may merely mean that we must modify some detail of the theory rather than abandon it, but there seems to come a time when too much "ad hockery" causes a theory to be abandoned, mainly on aesthetic grounds!

7. Repeated verification does not always increase the confidence in a result. Since around the time of the Stone Age the following experiment has been repeatedly done. When there is an eclipse of the sun then it is necessary to make a lot of noise to scare off the demon that is swallowing the sun, and this has infallibly worked; probably for every solar eclipse some people some place have made the necessary noise. To suggest that they should have tried not doing so on some occasion could have ended the world, so the suggestion is ridiculous.

8. Ockham's razor is often evoked, but what is simple and what is complex is subjective to say the least, and hence while useful at times, is also at times conveniently ignored. Thus in abstract algebra three conditions are usually given to define a certain thing, but a clever way can reduce them to two conditions. Simpler? It is unfortunately hard to go from the two to the three conditions, so most books make the larger number of assumptions. Indeed, by using suitable logical symbols many different statements can be combined into one. When is one statement simpler than many

statements?

9. The fruitfulness of a theory in suggesting other things to do is a criterion which is seldom mentioned, but it is important. A theory which asserts that everything that happens is that which a certain entity in a distant galaxy writes down, is a complete theory, it explains everything, but is useless currently and hence is sterile, so we do not seriously believe it. But it is not disprovable and it does explain everything!

10. It is said that at the bottom science is merely refined "common sense", but unfortunately there is no agreement on what "common sense" is, except that I have it and perhaps you do not!

11. It is well known that there can be several alternate theories to account for the same body of data, (just as quite different electrical networks can have the same transfer function), hence one theory cannot be "the right one", and all others are wrong. Indeed, Einstein observed that it is often the theory that makes the data, (much as this seems completely wrong to many experimentalists), rather than the data that makes the theory.

12. It is often claimed that science need only account for the observations, and make predictions accurately; "save the phenomena", as they often say, (listen to a lot of current quantum mechanikers as an illustration of this claim). But this flies in the face of what is often cited as a great step forward in science, the shifting from the Ptolmaic to the Copernican system (which I am told was at the time the less accurate in its predictions). Science is not merely a convenient mnemonic or prediction system, there is an "understanding of what is meant and how it works" that is essential if we are to make serious progress. Science is not mere formalism, contrary to many current writers and speakers, it is a way of thinking while trying to eliminate mysticism along the way. Unfortunately, all too often, scientists seem to want to inject needless mysticism into their theories, perhaps to make them more esoteric!

13. Science does not explain "why?". Even Newton knew that he did not explain gravity, he merely gave a formula to say how much it did. In all of science there is actually no "why", only "how", but the tight mesh of interrelationships of the "hows" gives us the feeling that gravity, for example, is "why" the planets and satellites behave as they do.

14. There is a belief that science is "objective" and has no "subjective" part. This is wishful thinking since we cannot achieve total objectivity, but we indeed try to approximate it. As noted earlier, the theory you hold to some extent influences what you see as data; we never see "reality" directly but only through a "window" of our expectations. True, we have learned to view things through various windows and this helps towards objectivity. But consider Eddington's well known story of the fishermen who went fishing in the sea with a net. They examined the size of the fish

they caught and decided there was a minimum size of the fish in the sea. The mental instrument you use influences what you see.

Thus there is apparently no such thing as "the scientific method" - the desire for a unique method is merely wishful thinking.

This is not to be interpreted to mean that all theories are equally good. When President Kennedy wanted to get to the moon in ten years; he could have appropriated the money for research in ESP and hence we could have organized group thought, and, via telekinesis, "thought" the people to the moon; or he could have spent it on churches to pray the people to the moon; but he chose to invest the money in crummy, old science.

In the long run the measure of science is in its effectiveness, both in coping with the world as we experience it, and also in the mental world where some theories are preferable to others because of the elegance and understandability and not only because of their effectiveness.

A simple test I often use when a new theory is expounded is when a person says, "It might be ...", or "It could be that ... ", I merely repeat the words with "not" inserted. In serious science every "might", "could" etc. should be quantified into a probability that the speaker is willing to bet on. I find that by using this approach many grandeloquent theories collapse.

Another test is the extent to which the speaker seeks out and mentions evidence that might disprove the claims. If potential contradictions must be forced on their attention then they are not honest scientists.

Thus what is science to one person may not be science to another person, it is variable depending on the situation and the people involved. At best science is a local social convention.

The appeal to authority is supposed to have no place in science, but it is often done. The problem a scientist faces is that while in a sense all previous theories have been proven to be wrong, still faced with an unexplained event does one consider it a miracle or else revise one's theory? We have found that the appeal to the past (authority) is usually, but not always, better than scrapping our current theories, but there is no sound method of deciding which to choose. The new theory when it is new can naturally explain less than the old, well developed theory, so the test of how much it can explain is not useful in the early stages. There one must depend on an indefinable "taste", "style", or whatever you care to call it, as to what to do; ignore, embrace, or stand on the sidelines and contribute nothing to the new theory if it wins out. It is not easy to be a good scientist, but it is easy to claim to be one!

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IN REPLY REFER TO:

26 August 1997

Ms. Rosalind Reid, Editor
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Dear Editor:

Enclosed, please find three copies of an article submitted for publication in the American Scientist. I am sure it will annoy a lot of people, but I think it should be published somewhere.

Sincerely

R.W. Hamming